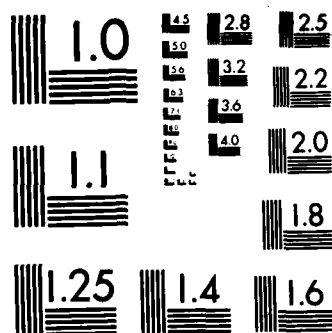


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An Inexpensive Intelligent Interface for Coupling a
PRA Fluorescence Lifetime Instrument to a Microvax II

by

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Isiah M. Warner

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AN INEXPENSIVE INTELLIGENT INTERFACE FOR COUPLING A PRA
FLUORESCENCE LIFETIME INSTRUMENT TO A MICROVAX II

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ABSTRACT

An inexpensive interface which can perform serial and parallel I/O operations necessary for instrument control and data transfer operations using time-correlated single photon counting instrumentation is described. Development of a compatible stepper motor system for controlling peripherals is also provided. This interface was implemented using an inexpensive Z80A based micro-computer.

1. INTRODUCTION

Several reasons can be cited for designing the interface described here. First, low cost solutions to the problem of instrument control and data analysis are needed. The cost of instrumentation is high and its purchase with a data reduction system can make it prohibitively expensive. Second, in-house computing capabilities of many laboratories make it unnecessary to have a separate dedicated computer for the instrument. In



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addition, the design of data evaluation software is often straight-forward. These considerations are appropriate for the setup and operation of fluorescence lifetime instrumentation.

The commercial availability of time-correlated single photon counting (TCSPC) fluorescence lifetime instrumentation allows luminescence lifetime measurements to be applied in a variety of research areas. In the analysis of fluorescent mixtures, both qualitative and quantitative information about the components can be obtained through the resolution of TCSPC data.¹ The use of emission monochromators has permitted time resolved emission spectra to be constructed from decay curves.² Molecular motions can be studied by measuring time resolved fluorescence depolarization³ and molecular distances are obtainable by evaluation of the rate of probe deactivation through resonance energy transfer.⁴ The sensitivity of luminescence lifetime to the molecular environment makes luminescent probes useful in protein chemistry⁵ as well as the study of the solvent environment around molecules.⁶ Such applications have demonstrated that TCSPC instrumentation is a valuable tool for the biologist, biochemist, and analyst in many areas of research.

The most common objective of the TCSPC experiment is to measure a luminescence decay curve from which the desired decay parameters can be obtained. The data is collected by a multichannel analyzer (MCA) as counts versus channels, where each channel corresponds to the number of luminescence events occurring in a given time interval. After the recording of hundreds of thousands of these events, the resultant data on the MCA is a histogram which corresponds to the decay profile of the sample. This profile is a convolution of the lamp profile with the luminescence decay curves. The lamp profile is then deconvoluted and the curve is evaluated to obtain the parameters of interest. This evaluation requires extensive computational methods, typically non-linear least-squares curve fitting, and generally

must be handled using a mini or main-frame computer. The design of such data evaluation software for TCSPC is fairly straightforward and several sample programs have been published in the literature.^{3,7,8}

2. INTERFACE DESIGN

Several factors were considered in designing the intelligent interface described here. These considerations are specific to the Photochemical Research Associates, Inc. (PRA) TCSPC lifetime instrumentation present in our laboratory. But, this interface can easily be used to control other instrumentation, due to its general configuration. The main requirement for our interface was compatibility with two RS-232 serial interface ports present on the MCA (a Tracor-Northern TN-7200, equipped with an options board and remote control options ROM) and RS-232 serial communications ports on the MicroVax II. In addition, the excitation and emission monochromators of the PRA TCSPC instrument may be driven by stepping motors. A four sample rotating cell holder may also be automatically controlled. Thus, at least three parallel ports for stepper motor control are needed. Remote operation and computer control of the instrumentation and data transfers were desired. However, monopoly of the MicroVax II CPU time would not be productive. Therefore, the interface device should also be programmable and able to store data prior to transfer to the MicroVax II.

The most obvious choice for such an interface is an inexpensive microcomputer. The TRS-80 Model IV is a good choice for several reasons. First, the computer is Z-80A based and communications ports can be added as Z-80A PIOs or Z-80A SIOs with relative ease. Second, the computer may be programmed in BASIC or assembly language for versatile instrument and communications control. The system is disk based, so data can be temporarily

stored and accumulated prior to transfer to the MicroVax II. The design and location of the hardware is favorable for adding to the system. Finally, the computer is inexpensive (<\$600) and reliable.

A. Control Signals Needed for I/O Expansion

The Z80A-PIO and Z80A-SIO/2 communications chips require the standard Z80 signals available on the CPU board.⁹ Both the PIO and SIO need the data bus (D0-D7), the clock (CLK), I/O request (IORQ), interrupt (INT), and read (RD). The SIO/2 requires both machine cycle 1 (M1) and reset (RESET). The PIO has no reset pin, so it uses the logical AND of M1 and RESET as its M1 signal and a chip reset. Each has a control/data select (C/D) and port A/port B select (A/B) which are controlled by the two least significant address lines (A0 and A1, respectively). Finally, each chip must be enabled through chip enable (CE). This signal is generated by decoding the signals on the four most significant address lines (A4-A7) using the 74LS138 3- to 8-line decoder/demultiplexer.¹⁰ These address lines are used because the TRS-80 reserves its own original I/O ports as 80H-FFH. Address line A7 can enable the decoder chip when it is low (address less than 80H) and A4-A6 will be decoded to enable the desired I/O chip.

The SIO/2 chips require that an external clock signal be input to control the communication baud rate. This clock signal must be significantly slower than the CPU clock, so a divider circuit must be used. We used an Intersil ICM7240 CMOS programmable counter/timer¹¹ and a 74LS93 4-bit binary counter to divide the CPU clock and generate the SIO/2 signal.

B. The Prototype Interface

Since three parallel and three serial interfaces are needed

for instrument control and data transfer, we decided to use three PIOs and three SIO/2s. This configuration provides six serial ports and six parallel ports. The I/O capabilities of this interface thus provide the necessary communications for many instrument control and data transfer applications. The CPU, along with the PIOs and SIO/2s, are placed on a double-sided printed circuit board, and connected to the motherboard CPU socket through the extended connector as shown in Figure 1. We chose this arrangement to circumvent the need to hardwire the CPU for connections to an external I/O board. Additionally, the I/O board can be mounted at the back of the TRS-80 through this arrangement. Additional I/O boards may be similarly mounted to extend the number of interface ports. Figure 2 shows the simplified circuit diagram for this I/O expansion board.

C. Stepper Motor Controllers

Stepper motor controllers are implemented on double-sided printed circuit boards. Figure 3 provides the circuit diagram. The controller board is based on the Cybernetic Micro Systems, Inc. CY512 stepper motor controller chip.¹² The input is buffered by a 74LS245 octal bus transceiver which prevents damage to the CY512 chip and serves as signal conditioner. The four phase outputs are input to a UNL2068B stepper motor driver chip (Sprague). Handshake logic is generated using a 74LS74 dual d-type positive edge triggered flip-flop with preset and clear. Several LEDs may be added to any of the CY512 outputs to indicate the status of the chip's operation. The LEDs can be driven by routing the desired signals to any hex buffer/drive with open collector outputs (i.e. 7407).

3. PROGRAMMING THE I/O BOARD AND STEPPER MOTOR CONTROLLER

The design of the I/O expansion board provides easy use of the I/O ports using the TRS-80 BASIC language. The peripherals are I/O mapped, and a unique address enables each chip. These chips can then be programmed for I/O by using the BASIC commands:

OUT address, databyte

IN address, databyte

By selection of the proper address, each PIO and each SIO/2 can be set up and I/O be performed from BASIC.

Setup of the PIOs and SIO/2s is accomplished by sending the control words specified in their respective manuals.^{13,14} The setup is simplified since we use a polled environment instead of interrupt driven I/O.

Control of the stepper motor is simple since the CY512 contains an extensive programming language of its own. The ASCII commands may be sent to the PIO controlling the appropriate stepper motor driver chip. This allows the CY512 to perform the desired action independent of the sending device.

4. IMPLEMENTATION OF THE INTERFACE

The excitation and emission monochromators have been coupled to SLO/SYN Synchronous/Stepping Motors (model M061-FC02, Superior Electric Co.) for computer control of wavelength positioning. In four-step mode, the motors were capable of wavelength positioning in 0.5 nanometer increments over the range of the monochromators. The cell holder is also equipped with a motor which allows any of the four cell positions to be set by computer control. These motors may run simultaneously since each is interfaced to a dedicated PIO port.

Control of the multichannel analyzer and data transfer is accomplished through the SIO/2 ports. Two serial ports are needed

to communicate with the multichannel analyzer, one for control, the other for data transfer. Control of the MCA involves issuing ASCII commands to the remote control port, and receiving status information back through that port. For this, one SIO/2 must be able to toggle quickly from an output to an input port between the sending and receiving of commands. This is accomplished by issuing control commands to the port from an assembly language subroutine called from BASIC. Another serial port is configured to receive data transmitted from the MCA. The data, accumulated on disk for several experiments, may then be transferred to the MicroVax II through a third SIO/2, set up for output.

Interface to the MicroVax II is accomplished by inserting a T-switch (Inmac 1863, 25 line T-switch) in the serial line from a remote terminal to the computer. A serial port from the described interface board is connected to the second T-switch port. The terminal is used to log-on and invoke the text editor and the serials is switched from the terminal to the serial interface, and data transfers to the MicroVax II. These transfers are carried out at 300 baud to prevent over-running the ability of the BASIC control program to send and receive data. Faster transfer speeds may be achieved by using machine language programs.

Control of all interface operations is accomplished by a menu driven TRS-80 BASIC controller program. All the operations of stepping motors and data transfer may be run interactively by an operator. The system may also be programmed to run without supervision or to allow data from one or more samples to be collected several times.

5. CONCLUSIONS

An inexpensive alternative to dedicated mini-computer control of TCSPC fluorescence lifetime instrument has been developed. This intelligent interface can provide versatile instrument

control in situations where computer access is already available, and researchers are willing to develop data analysis software.

One important area where the capability of the interface can be used is for the collection of TCSPC time-resolved emission data. The interface is able to obtain and store decay curves at several pre-programmed wavelengths, eliminating long hours of operator time and minimizing monochromator positioning errors.

Such an interface can also be used with instrumentation other than the TCSPC instrument. Any instrumentation which uses stepping motor control and/or needs serial or parallel data transfer to another computer could use the interface described in this manuscript. The PIO and SIO/2 chips can be added in any combination to this system, up to a maximum of thirty-two, with proper address decoding. Fluorescence and liquid chromatography instrumentation could benefit through the use of a similar controller.

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FIGURE CAPTIONS

FIGURE 1

I/O Interface Board Connection to TRS-80 Motherboard

FIGURE 2

Simplified Circuit Diagram for I/O Interface Board

FIGURE 3

Simplified Circuit Diagram for Stepper Motor Controller Board

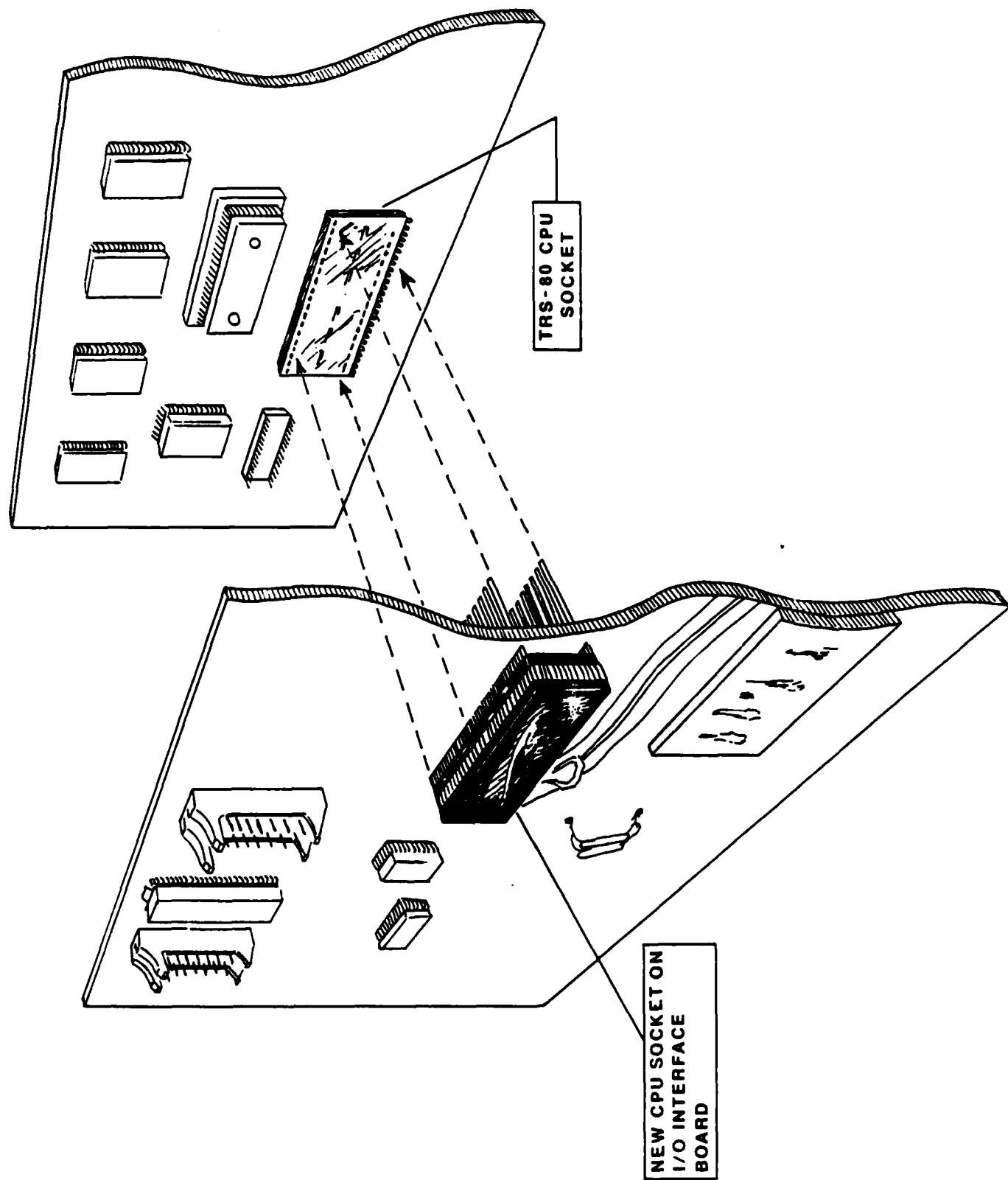
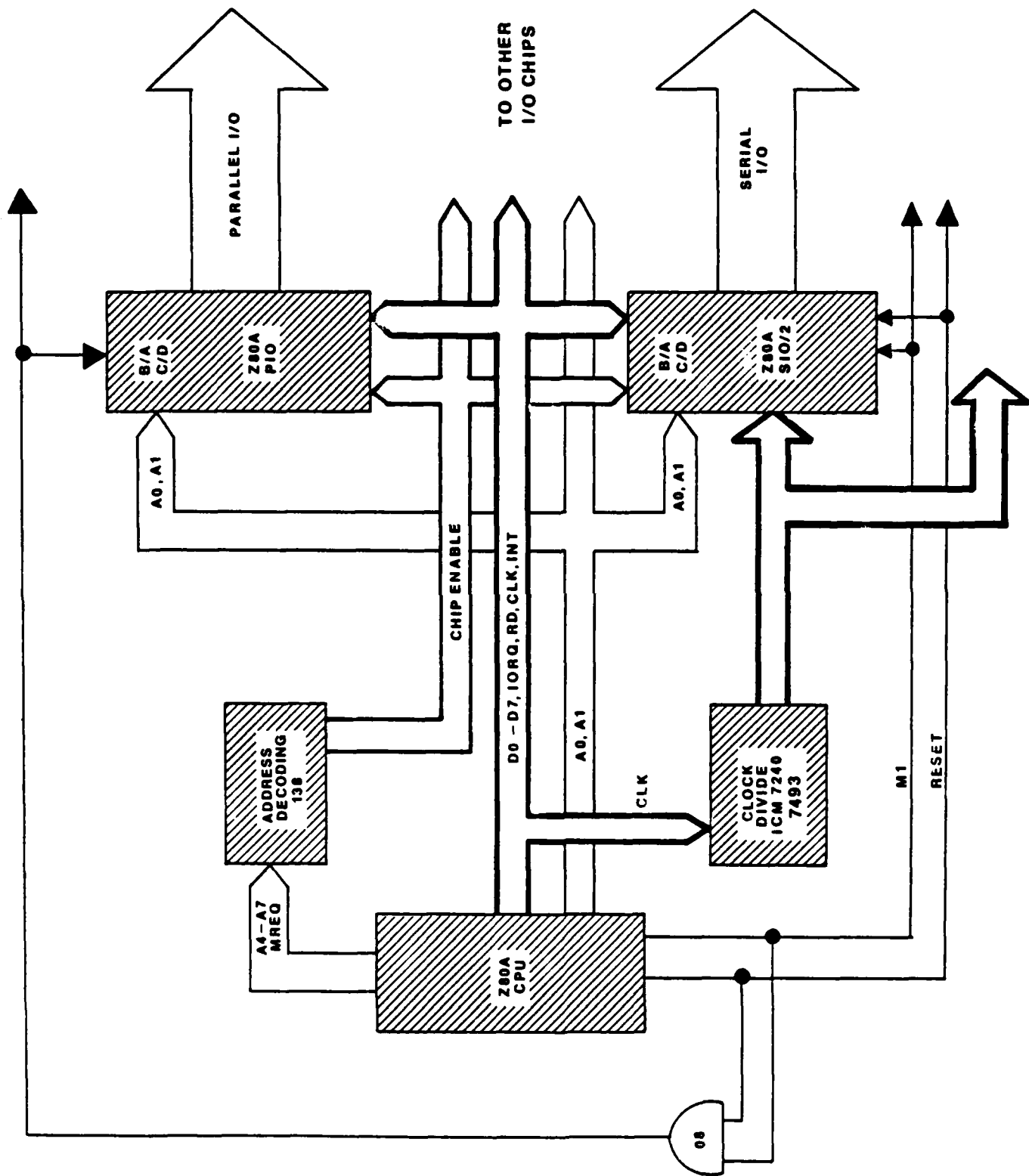


Figure 1



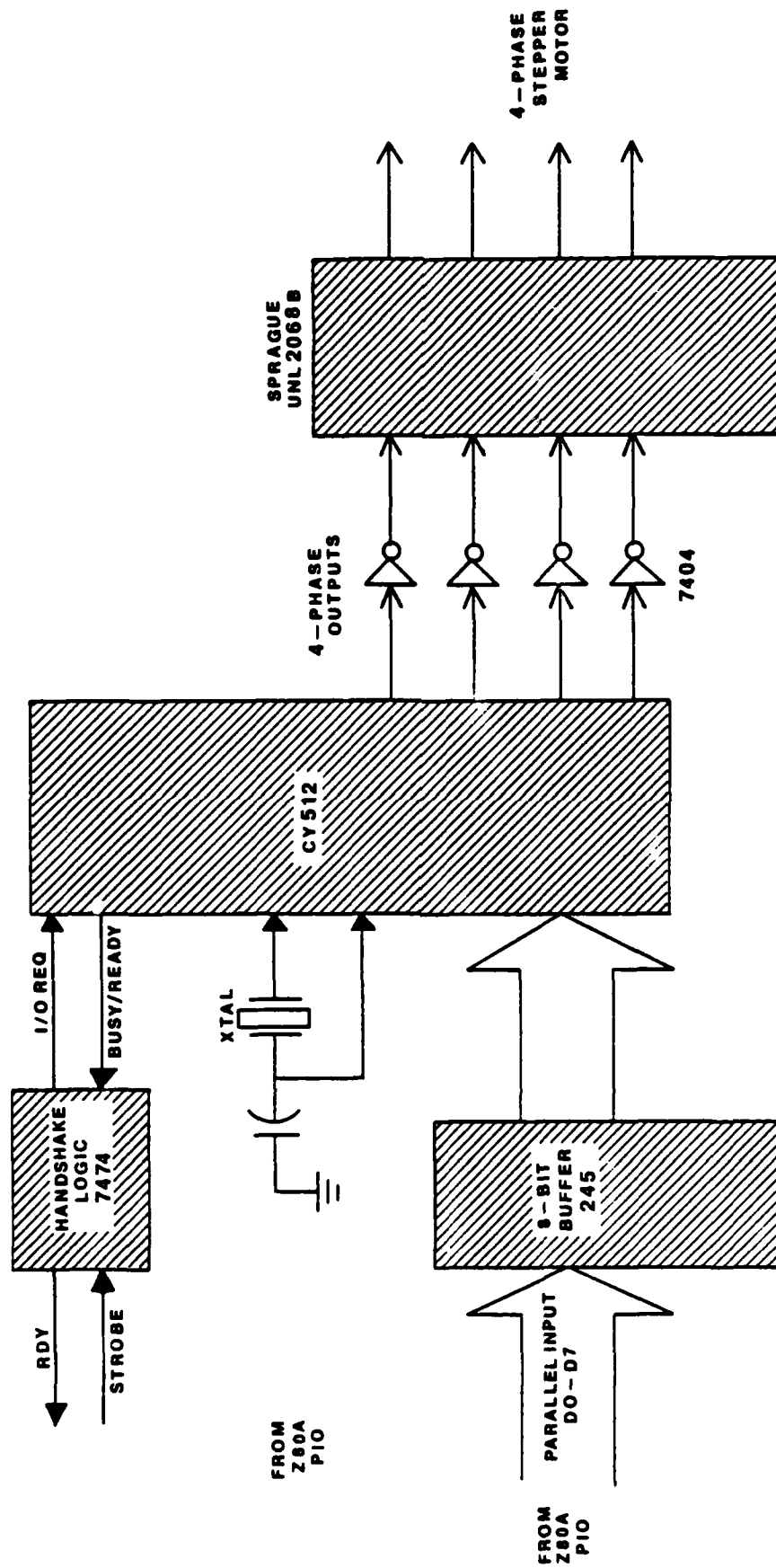


Figure 3

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